Report of FM Soundfield Study, Paremata School 1997

In 1997, the Oticon Foundation in New Zealand funded research into the use of the Phonic Ear F.M. Sound-field amplification system in junior classrooms. Initially it was difficult to decide on the research design. Carolyn Till, Audiologist from Hutt Valley Health and Suzanne Purdy, Senior Lecturer in Audiology, University of Auckland, contributed their time and expertise to initial discussions between Paremata School and Oticon, in the initial planning of this research project. In an attempt to ensure that measurements taken for changes in learning and behaviour were as objective as possible, we decided to do a literature search for suggestions of possible approaches from previous research projects.

Robyn Massie was undertaking a similar study in Australia and we used her research design as the basis for the one we undertook. Modifications to this design were made in consultation with Cedric Croft, chief researcher at the New Zealand Council for Educational Research.

Our research study was conducted in three junior classrooms, in two schools in the Porirua Basin (Paremata school and Windley school). The aims were: To determine the acoustic conditions existing in the classrooms.

To determine the incidence of hearing difficulties among the children.

To examine the effects of installing FM soundfield amplification systems on measures of speech intelligibility and on-task behaviour.

Many people contributed to the success of this project and I would like to thank the following:

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(*The rehabilitative value of sound field classroom amplification in rural indigenous primary school children. Revised research protocol, May 1996*)

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Joy Allcock.

INTRODUCTION

Language skills are central to educational success. As learning specialist Priscilla Vail (1) says, " *Kids with weak language face serious academic, social and emotional penalties."* In either spoken or written form we use language to communicate across all the curriculum areas.

There are a number of reasons why children have difficulties with language acquisition and related academic skills. They need opportunities to develop language skills and they have to be able to hear and process language.
Some children lack rich, early language experiences and their development is therefore slower. Some children's primary language is not the one they learn with at school. Some children have specific difficulties processing language and some children's language acquisition is hampered by health problems or environmental factors, which make speech intelligibility difficult.

Listening is critical to the process of language acquisition and therefore to the learning process. It requires a capacity for hearing, accurate perception of sounds and a good auditory memory that allows language to be stored and retrieved. Young children spend 45% to 60% of their school day involved in listening. (2)

WHAT FACTORS INTERFERE WITH THE DEVELOPMENT OF GOOD LISTENING SKILLS?

1. Factors within the child:

Intermittent or chronic, fluctuating hearing loss due to Otitis Media (glue ear), permanent hearing loss due to conductive or sensory-neural damage, auditory processing difficulties, attention difficulties.

2. Factors within the environment:

Background noise from outside the classroom (such as traffic noise, playground noise, noise from other classrooms, rain) and from inside the classroom (such as the noise of overhead projectors and computers, heating and ventilation systems, fish tanks, pets and children in the classroom).

Design of classrooms: The acoustic design of the classroom, which affects the intelligibility of speech by the way it influences reverberation (echoes) and absorption of sound.

1 FACTORS WITHIN THE CHILD

1.1 Permanent or fluctuating hearing loss

Children may have permanent hearing loss because of some damage to the structural mechanisms of hearing (conductive hearing loss) or because of damage to the sensory or neurological components of hearing. A fluctuating hearing loss is usually caused by Otitis Media which can become chronic and result in a condition called Otitis Media with Effusion, or glue ear as it is commonly known.
Although 85% of instances of otitis media resolve within 16 weeks, (3) children still have

compromised hearing for the time they are suffering from the condition.

The children in our research project underwent hearing testing on two occasions, eight weeks apart.
30% of the Paremata School children and 69% of the Windley School children failed on one of these occasions.
10% of children at Paremata and 54% of children at Windley failed on both occasions.
These children had compromised hearing for up to 8 weeks (20% of the school year). Many of them had hearing problems that continued for longer than this 8 week period.

Children in New Zealand are screened for hearing acuity in their first year at school. To be classified as a fail, children have to fail two tests carried out 16 weeks apart.
The national results from this screening, show that there is a variation in the geographical and ethnic incidence of hearing difficulties. In the 1996/97 year, children in the Hutt Valley Health District, where our research project was undertaken, had the highest failure rates in the country.
14.1% compared with the national average of 8.4%.
Maori children **– National average,13%. HVHD - 22%**
Pacific Island children – **National average, 16.1%. HVHD - 23.5%**
Other ethnic groups – **National average, 6.4%. HVHD -11.3%**

What are the implications of chronic or recurring Otitis Media on Learning?
Otitis Media is a very common health problem for many New Zealand children. Some cases of acute Otitis Media do not resolve and the condition becomes chronic. It may continue for months or years and hearing is compromised for this time. Children with acute or chronic Otitis Media may not show significant hearing loss in an audiogram where listening conditions are favourable. However, once they are back in a classroom with high levels of background noise and other unfavourable acoustic conditions they may not be able to hear speech sounds accurately.
Research carried out by Drs. Phil Silva, D Chalmers and I Stewart (4) in a longitudinal study of the health and development of approximately 1500 children born in Dunedin in 1972/3 showed that 6% of these children developed chronic Otitis Media with effusion (glue ear) in both ears. Their language development, speech articulation, and reading attainment fell significantly behind their peers and when they left school they were approximately two years behind in academic achievement. They also had a greater incidence of behaviour problems at school when compared with children who did not have bilateral glue ear.

1.2 Auditory processing and attention problems

Children without hearing difficulties may still have problems with listening. As children develop, they learn to screen out background noise and to pay attention to selected noises from their environment. They are unable to hear in background noise with the same skill as an adult until they reach the age of 13. (6) Many children, particularly in the junior school simply cannot listen selectively to the teacher's voice if there is other competing noise in the background because they have not yet developed the auditory perceptual skills to do so. They may be described as inattentive, distractible, disobedient, vague or disinterested. They may be all of those things but the underlying

reason may be that they have failed to pick up the message of what they should be doing.

Listening is a learned skill – it is a skill that needs to be taught and fostered. Children who can hear well in good acoustic conditions may show good listening strategies in these circumstances. However, if they are put into a situation where they have difficulty perceiving speech, they may cease to listen and if this continues over a long period of time, they may develop poor listening strategies. If children have to expend considerable conscious effort on listening they may be unable to attend to the cognitive tasks required of them. If listening is a constant effort, learning is affected. ***Children's ability to perceive speech sounds and to make sense of them, is therefore critical to the development of good listening skills, language acquisition and ultimately, to educational success.***

2. ENVIRONMENTAL FACTORS.

The key factors affecting the acoustic environment in classrooms are the level of background noise and the signal to noise ratio that exists.

2.1 Background noise levels.

The level of background noise that exists in an empty classroom is called the ambient noise level. International standards suggest that this level should be no higher than 30 to 35 dB for children with normal hearing. (7) In our study the ambient background noise levels were:

Paremata Room 14: 65dB - 30 dB higher than recommended
Room 3: 52dB - 17 dB higher than recommended
Windley Room 2/3: 60dB - 25 dB higher than recommended

The background noise levels were also measured with the children in the room, sitting silently on the mat and listening to the teacher speak. These measurements were:

Paremata Room 14: 60 dB - 25 dB higher than recommended
Room 3: 50 dB - 15 dB higher than recommended
Windley Room 2/3: 60dB - 25 dB higher than recommended

2.2 Signal to noise ratios.

This refers to the ratio of the signal (the teacher's voice) to the background noise. This has been shown in New Zealand and international research to be the most important area to consider when measuring classroom acoustics. International standards suggest measures of
between +12/+15 (minimum) and +20 dB (8) are necessary in order for children to hear efficiently in the classroom.
In 1994, Drs Blake and Busby (8) investigated the noise levels in 106 junior classrooms in the Wellington area. They found only 9% met the +12 minimum recommended for adequate signal to noise ratios. Most were considerably outside the recommended levels. Their results ranged from 0dB to +23dB with 20% in the 0dB range.

In our study we measured the signal to noise ratios in the three classrooms. They were:

Paremata school, Room 14 -5dB - 17 dB lower than recommended
Room 3 0 dB - 12 dB lower than recommended

Windley school, Room 6/7 1dB - 11 dB lower than recommended

What are the implications of poor acoustic conditions in classrooms, on learning outcomes?

International standards for background noise levels and signal to noise ratios are set for children with normal hearing. Children with compromised hearing (temporary and permanent) require much better conditions if speech is to be intelligible.

Speech intelligibility is crucial for children acquiring early literacy skills. As children begin to read and write, they learn that print maps the spoken word. There is a significant body of research which suggests that phonological awareness skills (the ability to discriminate between and isolate sounds in the spoken word) are critical to reading success. (13) In order to isolate and separate sounds in the spoken word and to discriminate between them, the young child must be able to **hear the sounds accurately.** For children who are learning to read and write in a language that is not their first language, speech intelligibility is even more critical to their success in literacy acquisition. Many sounds, particularly vowel sounds, are pronounced differently in different languages. Screening results from the National Audiology Centre suggest that many Maori and Pacific Island children may be starting school with a history of chronic glue ear, which impairs their ability to hear speech sounds clearly. They may also be learning to read and write in a language that is not their primary language and they may well be learning in classrooms with acoustic conditions that are significantly below acceptable international standards.

New Zealand participated in the International Survey of Reading Literacy in 1990. Children's reading achievement was measured at ages 9 and 14. There was a significant difference between the reading achievement of children whose first language was English and children who had English as a second language. The achievement levels for children learning with English as a second language were considerably lower.

In fact New Zealand had the largest home language gap of all countries participating in this survey.(10)

The Soundfield Amplification System Trial.

The Oticon Foundation in New Zealand funded a research study to determine the effect of FM soundfield amplification on classroom acoustics and children's learning. This research was undertaken in two schools in the Porirua basin – Paremata School (decile 9) and Windley School (decile 1a).

N.B. Decile ratings refer to socio-economic status with 10 being the highest and 1a being the lowest.

The study set out to find answers to these questions:

1. Does the use of the soundfield amplification system improve the signal to noise ratios in classrooms?

2. Does the use of the soundfield amplification system increase the amount of time children spend in on-task behaviour?

3. Does the use of the soundfield amplification system increase the amount of time children with poor hearing spend in on-task behaviour?

4. Does the use of the soundfield amplification system improve children's ability to discriminate between speech sounds in words?

1. Does the use of the soundfield amplification system improve the signal to noise ratios in classrooms?

The recommended background noise level in an empty classroom for children with normal hearing is 30-35dBA. The recommended signal–to-noise ratio is a minimum of 15dBA, meaning that the teacher's voice should be 15dBA louder than the background noise.

Classroom acoustic results – unamplified.

	Paremata		Windley
	Room 3	Room 14	Room 6/7
Background noise (empty)	52dBA	65dBA	60dBA
Signal-to-noise ratio	0dBA	-5dBA	+1dBA

Classroom acoustic results – amplified with soundfield system.

	Paremata		Windley
	Room 3	Room 14	Room 6/7
Background noise (empty)	52dBA	65dBA	60dBA
Signal-to-noise ratio	+8dBA	+5dBA	+6dBA

The use of the soundfield amplification system improved the signal-to-noise ratios by 10dBA, 8dBA and 5dBA. These figures are still below the recommended minimum, because of the high background noise levels that exist in the classrooms.

2. Does the use of the soundfield amplification system increase the amount of time children spend in on-task behaviour?

Children were observed for four 30 second periods, three times a week, over an eight week period. Each child was observed 96 times. The microphone was worn by the teacher throughout this eight week period but was turned off for two, 2 week blocks and on for a four week block.

Period one	Period two	Period three	Period four
2 weeks off	2 weeks on	2weeks on	2 weeks off

Comparisons of on and off-task behaviour were made between periods one and two (2 weeks off, 2 weeks on) and between periods three and four (2 weeks on, 2 weeks off).

PAREMATA SCHOOL RESULTS

Percentage of children showing changes in on-task behaviour.

more on-task behaviour	58%
no change	35%
less on-task behaviour	7%

The NZCER analysed the results of improvements in on-task behaviour with the system on, compared to on-task behaviour with the system off. This showed a statistical significance beyond 1 chance in a thousand.
$p > .0001$

WINDLEY SCHOOL RESULTS

Percentage of children showing changes in on-task behaviour

more on-task behaviour	85%
no change	15%
less on-task behaviour	0%

These results were not analysed by the NZCER for statistical significance

Changes in on-task behaviour across both schools.

Changes in on-task behaviour with the soundfield system on, ranged from being 14% less on-task to 50% more on-task. On average, children spent 18% more time on-task when the soundfield system was on than they did when it was off.

3. Does the use of the soundfield amplification system increase the amount of time children with poor hearing spend in on-task behaviour?

Children in this study were given an audiogram (to measure hearing acuity) and a tympanogram (to measure pressures in the ear) at the beginning and the end of the eight week period.
Changes in on-task behaviour with the soundfield system on and off were compared for all children who failed one or more of these audiograms or tympanograms. The improvements in on-task behaviour that these children showed with the soundfield system on, were analysed by the NZCER, and were shown to be statistically significant at 5 chances in 1000. $p > .005$

4. Does the use of the soundfield amplification system improve children's ability to discriminate between speech sounds in words?

We used the Test of Phonological Awareness (9) to measure children's ability to hear and discriminate between speech sounds. This test was carried out without the use of the soundfield system at the beginning of the study and with the soundfield system eight weeks later, at the end of the study. The results were recorded as stanine scores between 1 and 8. Results from parallel classes, which did not use the soundfield system at any time, were compared with the amplified classes.
These are the results:
Paremata school.

Amplified classrooms	Improvements of 1 stanine or more	74%
Parallel classes	Improvements of 1 stanine or more	46%
Amplified classrooms	No change	18%
Parallel classes	No change	48%
Amplified classrooms	Decreased 1 stanine or more	8%
Parallel classes	Decreased 1 stanine or more	7%

Windley school
No parallel classes were tested, but these are the changes recorded in the amplified class.

Improvements of 1 stanine or more	64%
No change	27%
Decreased 1 stanine or more	9%

SUMMARY

The quality of the listening environment in the classroom affects all children who learn in it and has consequences for their learning success. For children with fluctuating or permanent hearing loss, for children who have English as a second language and for children who have difficulties paying attention to, remembering and processing auditory information, the consequences are likely to be considerable.

Our research has highlighted three areas of concern.

1. The high incidence of hearing difficulties.

Many of the children had Otitis Media and their hearing would be compromised for the duration of time their ears were not functioning normally.

2. The high levels of background noise in classrooms.

These levels were considerably higher than the 30 to 35dB level recommended as necessary for children with normal hearing, to be able to understand speech in a classroom situation. The recommended levels for children with impaired hearing are even lower.

3. The poor signal to noise ratio in the classroom.

Recommended levels for children to be able to hear and understand the teacher's voice are between +12/15dB and +20dB. The teacher's voice needs to be this much louder than the background noise level for speech to be intelligible to children with normal hearing.

The listening environment in the classroom is vitally important to the learning process. Young children especially, are dependent on good acoustic conditions for the development of their language skills. In today's information-based society, the ability to use language in its written and spoken form is essential. Academic success is dependent on reading and writing skills as they form the basis of educational assessments from primary to tertiary levels.

Good listening skills are imperative for the development of language. Listening skills are learned and may be negatively affected by poor listening conditions, hearing difficulties, central auditory processing difficulties, attention difficulties and learning in a language that is not the learner's primary language.

These factors cannot be changed in the immediate future. Children will continue to learn in classrooms with poor acoustics; they will continue to suffer from glue ear and other conditions that affect hearing; they will continue to experience attention and auditory processing difficulties; there will continue to be a significant proportion of the New Zealand population who have English as a second language. We need to continue with current initiatives and develop new ones aimed at improving educational outcomes for these children.

The sound-field amplification systems we have been trialling in our research, have been used in many schools in the United States for the past 15 years. (12) The positive results we obtained in our research are in line with those from other international studies. Sound-field amplification systems are able to instantly change the acoustic environment in the classroom by providing a much better signal to noise ratio with the flick of a switch. The signal to noise ratio is the acoustic condition that

has been shown to be the most significant factor in improving the listening environment in the classroom. If we fitted all junior classrooms with these devices, we would be providing our children with significantly improved learning environments at the most crucial time in their school careers – the time when they are learning to turn the spoken word into written language.

The effects of poor acoustic conditions in classrooms, on children's learning success is not a new concern. Mark Ross (11) said in 1972:
"*Whole generations of children are being maleducated while presently available information slowly filters down to the classroom. The recognition and correction of the negative effects of classroom acoustics is an example of one such area*." (p.770.)

If we are really serious about improving the literacy of New Zealand children, the effects of hearing problems and poor classroom acoustics must be addressed.

Joy Allcock
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References

1. Vail, P. (1996). Words Fail Me. How language develops and what happens when it doesn't. N.J:Modern Learning Press.

2. Butler, 1975, cited in Rosenberg, G.G. Improving Classroom Acoustics: Enhancing listening and learning environments with FM soundfield classroom amplification. IDEA, Part B, Special Project.

3. New Zealand Hearing Screening Statistics, July 1996 – June 1997. Report to the Transitional Health Authority, January 1998. National Audiology Centre. Auckland.

4. Silva, A., Chalmers, D., & Stewart, I. (1986). Some audiological, psychological, educational and behavioural characteristics of children with bilateral otitis media with effusion: A longitudinal study. Journal of Learning Disorders, Vol. 9, 3. 165-169.

5. Dryden, G., & Vos, J. (1993). The Learning Revolution NZ: Profile Books.

6. Neuman, A.C., & Hochberg, I. (1983). Children's perception of speech in reverberation. Journal of the Acoustical Society of America. Vol. 73, 6. 2145-2149.

7. Coddington, K. (1980). Classroom acoustics and their relationship to children with hearing losses in normal schools. Paper from the National Acoustics Centre, Auckland.

8. Blake, P., & Busby, S. (1994) Noise levels in New Zealand junior classrooms: Their impact on hearing and teaching. NZ Medical Journal, September, 1994. 357-358.

9. Torgesen, J.K. & Bryant, B.R. (1994). Test of Phonological Awareness Texas: pro-ed.

10. Wilkinson, I.A.G.(1997). Closing the gender and home-language gaps. in reading literacy. Set Special, 1997. Language and Literacy. NZCER.

11. Ross, M. (1972) Classroom acoustics and speech intelligibility. (full reference unavailable)

12. ***Papers that discuss research supporting the use of FM sound-field amplification systems.***

Allen, L. (1993). Promoting the usefulness of classroom amplification equipment. Educational Audiology Monograph 3

Crandell, C.C. (199). The effects of classroom acoustics on children with normal hearing: Implications for intervention strategies. (full reference unavailable at present time)

Crandell, C.C. (1996). Effects of sound field FM amplification on the speech perception of ESL children. Educational Audiology Monograph 4.

IDEA, Part B, Special Project. Improving Classroom Acoustics. Enhancing listening and learning environments with FM Soundfield classroom amplification.

Warner, W.A. (1988). An inexpensive group FM amplification system for the classroom. Volta Review, Jan. !988.

Zabel, H., & Tabor, M. (1993). Effects of soundfield amplification on spelling performance of elementary school children. Educational Audiology Monograph,3.

13. ***Papers that discuss the relationship between spelling and reading success and phonological awareness.***

Bruck, M., & Treiman, R. (1990). Phonological awareness and spelling in normal children and dyslexics: The case of initial consonant clusters. Journal of Experimental Child Psychology, 50. 156-178.

Castles, J.M., Riach, J., & Nicholson, T. (1994). Getting off to a better start in reading and spelling: The effects of phonemic awareness instruction within a whole language program. Journal of Educational Psychology,86,(3). 350-359.

MacDonald, G.W., & Cornwall, A. (1995). The relationship between phonological awareness and reading and spelling achievement, eleven years later. Journal of Learning Disabilities, 28,(8). 523-527.

Morais, J. (1991). Constraints on the development of phonemic awareness. In S.A. Brady & D.P. Shankweiler (Eds.) Phonological processes in literacy: A tribute to Isabelle Y. Liberman (pp 5-28).

Rohl, M., & Tunmer, W.E. (1988). Phonemic segmentation skill and spelling acquisition. Applied Psycholinguistics, 9. 335-350.
NJ: Lawrenc Erlbaum Associates.

Treiman, R., & Baron, J. (1983). Phonemic-analysis training helps children benefit from spelling-sound rules. Memory & Cognition,11 (4). 382-389.

Treiman, R., & Zukowski, A. (1991). Levels of phonological awareness. In S.A. Brady & D.P. Shankweiler (Eds.) Phonological processes in literacy. A tribute to Isabelle Y. Liberman (pp 67-84). NJ: Lawrence Erlbaum Associates.